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NON-PROVISIONAL APPLICATION FOR LETTERS PATENT
UNITED STATES OF AMERICA

Be it known that I, Edward Kachnic, residing at 4026 Hickory Nut Drive, Douglasville, Georgia 30135, a citizen of the United States, and I, Benjamin Pryhoda, residing at 530 Arbor Drive, Lafayette, Colorado 80026, have invented certain new and useful improvements in a

SENSORY INSPECTION SYSTEM AND METHOD THEREOF

of which the following is a specification.

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SENSORY INSPECTION SYSTEM AND METHOD THEREOF

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PRIORITY CLAIM AND CROSS REFERENCES

The present application is a continuation-in-part and claims the benefit of pending nonprovisional patent application, serial No. 10/452,698, filed June 2, 2003, entitled WIRELESS IMAGE PROCESSING METHOD AND DEVICE THEREFOR, which is a continuation-in-part and, like the present application, claims the benefit of pending nonprovisional patent applications, serial No. 09/644,389, filed August 23, 2000, entitled PART-FORMING MACHINE CONTROLLER HAVING INTEGRATED SENSORY AND ELECTRONICS AND METHOD THEREOF, and serial No. 10/246,974, filed September 19, 2002, entitled PART-FORMING MACHINE CONTROLLER HAVING INTEGRATED SENSORY AND ELECTRONICS AND METHOD THEREOF, which are nonprovisional patent applications of provisional patent application, serial No. 60/212518, filed on June 19, 2000, entitled PART-FORMING MACHINE CONTROLLER HAVING INTEGRATED SENSORY AND ELECTRONICS AND METHOD THEREOF; pending nonprovisional patent application, serial No. 09/728,241, filed December 1, 2000, entitled PART FORMING MACHINE HAVING AN INFRARED VISION SYSTEM AND METHOD FOR VERIFYING THE PRESENCE, ABSENCE AND QUALITY OF MOLDED PARTS THEREIN; pending nonprovisional patent application, serial No. 09/738,602, filed December 16, 2000, entitled PART-FORMING MACHINE HAVING AN IN-MOLD

INTEGRATED VISION SYSTEM AND METHOD THEREFOR; pending nonprovisional patent application, serial No. 10/293,846, filed November 13, 2002, entitled PART-FORMING MACHINE HAVING AN IN-MOLD INTEGRATED VISION SYSTEM AND METHOD THEREFOR; and pending nonprovisional patent application, serial No. 10/441,338, filed May 20, 2003, entitled PART-FORMING MACHINE HAVING AN IN-MOLD INTEGRATED VISION SYSTEM AND METHOD THEREFOR; wherein the present application claims benefit to all of the above-listed applications to the fullest extent permitted by law.

TECHNICAL FIELD

The present invention relates generally to sensory inspection devices and methods, and more specifically, to a machine vision inspection system and method for verifying the presence, absence and/or quality of a target. The present invention is particularly suitable for, although not limited to, use with a part-forming machine wherein the status of a molded part relative to a mold is the focal point of the sensory inspection.

BACKGROUND OF THE INVENTION

Sensory inspection systems, such as machine vision systems, are relied upon throughout a vast array of industries for computerized

inspection of parts and assistance in/direction of operational control of automated and semi-automated systems for the production and/or manipulation thereof. Products particularly suitable for utilization of such image analysis methods include, for instance, formed or molded plastic parts, semiconductors and machined parts. Other uses of sensory inspection systems include the examination of remote, otherwise inaccessible cavities, such as within a fuel cell or jet engine, wherein identification of stress failures and/or otherwise weakened components is critical.

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In each instance, a variety of sensory data is acquired from a target site and is analyzed by a computer according to a comparative or otherwise objective specification. The analysis results are reported to a controller, whereby decisions are influenced and/or actions are directed as a result thereof.

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The parts-forming industry is but one of the regular users of such systems, albeit one of the world's largest industries in both total revenue and employment. As a multi-billion dollar industry, even small improvements to equipment design can provide an enormous increase in the efficiency of the manufacturing process and thereby generate a tremendously beneficial financial impact, especially for volume-oriented automated producers. Thus, numerous methods and machines have been designed for forming parts.

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Formed parts are generally created via molds, dies and/or by thermal shaping, wherein the use of molds remains the most widely utilized. There are many methods of forming a part via a mold, such as, for exemplary purposes only, stretch-blow molding, extrusion blow molding, vacuum molding, rotary molding and injection molding. Injection molding is one of the most popular methods and is a method wherein the utilization of sensory inspection, such as via machine vision methodology, can increase efficiency via improved quality of task performance and increased part production.

Injection molding systems are typically used for molding plastic and some metal parts by forcing liquid or molten plastic materials or powdered metal in a plastic binder matrix into specially shaped cavities in molds typically having two separable portions or mold halves, where the plastic or plastic binder matrix is cooled and cured therein to make a solid part or parts. For purposes of convenience, references herein to plastic and plastic injection molds are understood to also apply to powdered metal injection molding and other materials from which shaped parts are made by injection molding, even if they are not mentioned or described specifically. The nature of the molding process dictates that the monitoring and reporting on system operational parameters and/or part formation is critical to high-throughput requirements.

One such operational parameter is the automated control of ejector apparatus that typically dislodges or pushes hardened plastic parts from a mold cavity, wherein a typical ejector apparatus
5 includes one or more elongated ejector rods extending through a mold half into the cavity or cavities and an actuator connected to the rod or rods for sliding or stroking them longitudinally into the cavity or cavities to push the hard plastic part or parts out of the cavity or cavities. Other types of ejector apparatus are also utilized,
10 such as robotic arms, scrapers or other devices. However, it is recognized that machine vision systems may be utilized to influence the operation of any type of ejector apparatus, any other type of operational parameter for an automated or semi-automated part-forming machine, or any other type of automated or semi-automated production
15 or inspection system.

With respect to the utilization of machine vision systems for operational control of ejector apparatus of a part-forming machine, because it is not unusual for a hard plastic part to stick or hang-up
20 in a mold cavity in spite of an actuated ejector, prior to the introduction of machine vision systems, one common technique was to design and set the ejectors to actuate or stroke multiple times in rapid succession, such as four or five cycles each time a hard plastic part is to be removed, so that if a part sticks or is not

removed from a mold cavity the first time it is pushed by an ejector, perhaps it can be dislodged by one or more subsequent hits or pushes from the ejectors. Through the use of machine vision systems, however, additional time previously required for pre-set multiple
5 ejector cycling could be substantially eliminated and wear and tear on the ejector equipment and molds could be reduced. Moreover, damage to molds and lost production time from stuck or otherwise incompletely ejected hard parts can be avoided by visual inspection.

Thus, such improvements, over the course of days, weeks, and months
10 of injection molding parts in repetitive, high volume production line operations, can significantly bear on production quantity and cost factors.

One example, U.S. Patent No. 5,928,578, issued to Kachnic et
15 al., provides a skip-eject system for an injection molding machine, wherein the system comprises a vision system for acquiring an actual image of an open mold after a part ejector has operated and a controller for comparing such actual image with an ideal image of the open mold to determine if the part still remains in the mold. As
20 such, signals to and from the machine controller in response to the image analysis are critical to ensure proper and timely automatic cycling.

Typical systems require the use of separate controllers to

receive input signals, provide data comparison and/or determine sensory parameters and then generates the proper output signal to the sensory device and/or to the molding machine controller. As an example, a sensory controller, such as a machine vision system, has
5 sensory input, such as a camera image(s), which typically are analyzed two times per cycle. The first analysis typically is immediately after the mold open complete signal from the molding machine is given to the sensor system controller. The purpose is to verify the presence of parts in the moving side of the mold. If the
10 analysis is affirmative, then it is concluded that parts have left the fixed side of the mold and are present on the moving side of the mold. The second analysis is typically after the molding machine has signaled to the sensory controller that the part ejection portion of the molding cycle is complete. Many times this includes several
15 ejection strokes. The purpose is to verify the absence of parts in the moving side of the mold. If the analysis is affirmative, then it is concluded the moving side of the mold has parts removed. Signal inputs into the machine controller are typically digital outputs from the sensory controller. Signals from the machine controller are
20 typically digital inputs into the sensory controller.

There are many variations to the above example, however essentially all include a sensory controller, sensor input(s) to the sensor controller, analysis of the input data, and a digital

input/output resultant scheme to the machine controller. This methodology duplicates the user interface and requires an independent CPU hardware system, digital input/output interface and associated cabling thereby substantially increasing the costs of the system. In addition, as more interfaces, CPUs and cabling are added to a data system, the system becomes inherently less reliable. Moreover, with prior systems, the machine controller polls data input/output from the sensor controller and then waits for the data. In extremely time sensitive automatic cycling systems such as injection molding machines, even slight delays can affect the overall efficiency of the system and result in substantial increase in the cost of goods.

Additionally, while each sensory improvement can and does increase quality and productivity for part-forming processes, resultant increases in cabling and wiring between components introduce practical limitations. Typical system-level solutions for machine vision applications include a CCD (charge-coupled device) or CMOS (complementary metal-oxide semiconductor) camera having sensors combined with RAM (random access memory), a microprocessor and cabling combined with firmware and/or software analysis features. Thus, while more electronic capability can be placed at the viewing position, physical limitations result from incorporating all necessary hardware and image processing firmware into the same package.

Physical location of the camera, for instance, can be critically important. Most systems have typically utilized CCD cameras positioned on the top or sides of the mold to acquire an image of the mold. CCD cameras view objects within the visible light spectrum typically defined as electromagnetic radiation between 400nm and 780nm in wavelength and, as such, are dependent upon and affected by the lighting environment surrounding the molding machine. This requires that the mold be completely opened before an image can be acquired, thus slowing down the inspection process. Moreover, due to the angle of the sensing device relative to the mold, a skewed image is acquired thereby resulting in decreased resolution of the image and increased inspection error.

Therefore, it is readily apparent that there is a need for a sensory inspection system and method that can reduce the added costs of having an independent sensor controller and reduce the data processing time of prior systems and thus, improve efficiency and that can incorporate wireless image processing capabilities, wherein physical limitations can be minimized or overcome, enabling integration of an in-mold vision sensor that can provide data acquired at a relatively parallel angle from the sensor, data that is not affected by fluctuations in environmental lighting, and wherein a remote host computer can be utilized to process the sensory data,

thereby enabling the utilization of a competitively priced and easily replaceable high performance, off-the-shelf host computer, enabling host miniaturization of the image sensor for smaller implementations, and enabling concurrent analysis of a plurality of sensors by one remote host, thus eliminating costly customized direct wiring expenses and avoiding the above-discussed disadvantages.

BRIEF SUMMARY OF THE INVENTION

10 Briefly described, in a preferred embodiment, the present invention overcomes the above-mentioned disadvantages and meets the recognized need for such a device by providing a sensory inspection system and method incorporating wireless processing methodology for utilization in combination with a machine vision system, preferably a
15 part-forming machine having integrated sensory and electronics, thereby minimizing and/or eliminating physical cabling and wiring constraints to enable smaller implementations, and enabling essentially limitless physical configurations, increased analysis capabilities, and improved price/performance ratios.

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According to its major aspects and broadly stated, the present invention is a wireless inspection system for verifying the presence, absence and quality of a selected target, wherein the sensory components can be positioned within the target location,

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to facilitate flexibility of sensory components, thereby enabling maximized quality of target data and accurate inspection of remote, otherwise inaccessible targets.

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to be incorporated with a part-forming machine to facilitate in-mold positioning of sensory components.

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to incorporate near-infrared inspection capabilities to capture images of a target site and determine the presence, absence and/or quality of a target object or feature.

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to facilitate placement of sensors to enable visual data to be acquired with minimized distortion from acquisition angles and with minimized effects from environmental conditions.

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to facilitate incorporation of sensors within a part-forming machine mold, thereby increasing the available data input window by allowing images to be
5 acquired during the mold-opening process.

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to conduct
10 sensory inspection and data acquisition accurately in any of a multitude of visible light intensities and settings.

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to facilitate
15 quick and efficient component exchange and/or replacement without necessitating wiring, rewiring or other installation complications.

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to facilitate
20 the synergistic combination of a multitude and/or variety of sensory devices.

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to enable integration of the sensory processing with the machine controllers.

5 Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to eliminate waiting for polling of digital input/output interface signals from the sensor controller, and thus, the continuation of machine cycles is more efficient due to closer coupling of the analysis result and
10 the machine process.

Another feature and advantage of the present invention is the ability of such a sensory inspection system and method to provide an integrated quality control inspection station, which detects,
15 measures, and/or sorts for quality defects. For example, in use with a part-forming machine, parts can be inspected on the parting line surface in the mold or removed from the mold via a robotics type device and presented to one or more sensors. Quality data can be processed before or in parallel with the next molding cycle to
20 determine pass or fail of the inspection criteria. Feedback to the molding process can be given to continue, adjust the process, or stop the molding process and wait for manual intervention. Part quality is verified and the overall part forming process is improved by reducing the number of defective parts produced.

These and other objects, features and advantages of the invention will become more apparent to one skilled in the art from the following description and claims when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood by reading the Detailed Description of the Preferred and Alternate Embodiments with reference to the accompanying drawing figures, in which like reference numerals denote similar structure and refer to like elements throughout, and in which:

FIG. 1 is a functional diagram of a sensory inspection system and method according to a preferred embodiment of the present invention;

FIG. 2 is a partial cross-sectional side elevation view of a typical injection molding machine showing a machine vision sensor and showing the ejectors retracted;

FIG. 3 is a partial cross-sectional side elevation view of the injection molding machine of **FIG. 2** showing the ejectors extended;

FIG. 4 is a diagrammatic representation of a sensory inspection system and method according to a preferred embodiment of the invention;

FIG. 5 is a diagrammatic representation of a sensory inspection system and method according to an alternate embodiment of the invention;

FIG. 6 is a functional diagram of a sensory inspection system and method according to an alternate embodiment of the present invention.

FIG. 7 is a plane view of a representative pixel grid area of a prior-art vision system showing the effects of a skewed view on pixel area.

FIG. 8 is a plane view of a representative pixel grid area of the present invention showing the reduced view area of each pixel.

DETAILED DESCRIPTION OF THE PREFERRED AND ALTERNATE EMBODIMENTS

In describing the preferred and alternate embodiments of the present invention, as illustrated in the figures and/or described

herein, specific terminology is employed for the sake of clarity. The invention, however, is not intended to be limited to the specific terminology so selected, and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner to accomplish similar functions.

With regard to all such embodiments as may be herein described and contemplated, it will be appreciated that optional features, including, but not limited to, aesthetically pleasing coloration and surface design, and labeling and brand marking, may be provided in association with the present invention, all without departing from the scope of the invention.

To better understand the present system and method of this invention, it will be specifically explained in the context of a particular machine vision system, that is, its preferred use in conjunction with an injection molding system. However, it is expressly understood and contemplated that the sensory inspection system and method described herein is suitable for utilization in combination with any machine system such as, for exemplary purposes only, for the inspection of machined parts, for inspection of remote, otherwise inaccessible targets and for monitoring of automated production performance and quality.

With reference to the preferred, exemplary use in combination with an injection molding machine and the process thereof, referring first to **FIGS. 2-3**, a conventional automated injection molding machine 10 is shown equipped with a mold 12 comprising two mold halves 14, 16, a sliding rod-type ejector system 18, and sensor 20 for acquiring visual images of the open mold half 14 in electronic format that can be digitized, stored in memory, and processed to detect presence or absence of a plastic part or material in the mold half 14. Preferably, sensor 20 is a near-infrared (IR) camera 310 for acquiring visual near-infrared images; however, any suitable sensor or camera may be utilized, such as, for exemplary purposes only, a CMOS (complementary metal oxide semiconductor) or CCD (charge-coupled device) array electronic camera 20 for acquiring visual images in electronic pixel format, a video data collection terminal, an ultrasonic sensor or any suitable optical imaging device capable of generating computer readable image data of a visual representation.

Preferably, visual images of the open mold half 16 are acquired in electronic pixel format that can be digitized, stored in memory, and processed to detect presence or absence of a plastic part or material in the mold half 16. It is important to understand, however, that present invention will also work just as well with any of the part or material sensor or detection systems or techniques.

mentioned above as well as many others; therefore, while the system and method of the present invention is described conveniently with the typical, conventional injection molding apparatus described herein, it is not limited to application or implementation with only
5 such conventional apparatus.

In general, the exemplary conventional injection molding machine
10 comprises two platens 24, 26 mounted on a frame made of four elongated, quite substantial frame rods 28, 30, 32, 34 for mounting the two halves 14, 16 of mold 12. Stationary platen 24 is immovably
10 attached to rods 28, 30, 32, 34, while moveable platen 26 is slidably mounted on rods 28, 30, 32, 34 so that it can be moved back and forth, as indicated by arrow 36, in relation to stationary platen 24.

Therefore, mold half 16 mounted on moveable platen 26 is also
15 moveable as indicated by arrow 36 in relation to the other mold half 14 that is mounted on stationary platen 24. A large hydraulic or mechanical ram 38, which is capable of exerting a substantial axial force, is connected to moveable platen 26 for moving mold half 16
into contact with mold half 14 and holding them together very tightly
20 while liquid or molten plastic 40 is injected into mold 12, as best seen in **FIG. 2**.

Most molds 12 also include internal ducts 15, 17 for circulating heating and cooling fluid, such as hot and cold water, through the

respective mold halves 14, 16. Cooling fluid supply hoses 19, 21 connect respective ducts 15, 17 to fluid source and pumping systems (not shown). Hot fluid is usually circulated through ducts 15, 17 to keep mold 12 hot during the injection of liquid or molten plastic 40 into cavity 50. Then, cold fluid is circulated through ducts 15, 17 to cool mold 12 to allow the liquid or molten plastic 40 to solidify into hard plastic part 22.

A typical plastic injector or extrusion system 42 may comprise an injector tube 44 with an auger 45 in tube 44 for forcing the liquid or molten plastic 40 through aperture 46 in stationary platen 24 and through duct 48 in mold half 14 into mold cavity 50 that is machined or otherwise formed in mold half 16. In many applications, there are more cavities than one in mold 12 for molding cycle. In such multiple cavity molds, multiple ejectors may be required to eject the hard molded parts from all of the cavities. Plastic extrusion system 42 also includes a hopper or funnel 52 for filling tube 44 with the granular solid plastic 41, a heating coil 47 or other heating system disposed around tube 44 for heating granular plastic 41 enough to melt it in tube 44 to liquid or molten plastic 40, and motor 54 for driving auger 46.

After the liquid or molten plastic 40 is injected into mold 12 to fill mold cavity 50, as illustrated in **FIG. 2**, and after the

plastic 40 in mold cavity 50 has solidified as described above, ram 38 is actuated to pull mold half 16 away from the mold half 14 so that hard plastic part 22 can be ejected from mold cavity 50. Once mold halves 14, 16 begin to separate, machine controller 72 sends a signal to sensor 20 to acquire a first image of mold half 16, wherein the image is analyzed to ensure the presence of part 22 in mold half 16.

Ejection of hard plastic part 22, as mentioned above, can be accomplished by a variety of mechanisms or processes, and the ejector system 18 illustrated in **FIGS. 2-3** is but one example. Ejector system 18 includes two slidable ejector rods 56, 58 that extend through moveable platen 26 and through mold half 16 into mold cavity 50. When mold 12 is closed for filling mold cavity 50 with plastic 40, as shown in **FIG. 2**, ejector rods 56, 58 extend to, but not into, mold cavity 50. However, when mold 12 is opened, as shown in **FIG. 3**, ejector actuator 60, which comprises two small hydraulic cylinders 62, 66 and cross bar 68 connected to ejector rods 56, 58, pushes ejector rods 56, 58 into mold cavity 50 to hit and dislodge hard plastic part 22 and push it out of cavity 50. Because one hit or push by ejector rods 56, 58 is occasionally not enough to dislodge and push hard plastic part 22 all the way out of cavity 50, it is a common practice to cycle ejector actuator 60 several times to cause ejector rods 56, 58 to reciprocate into and out of cavity 50.

repetitively so that, if hard plastic part 22 is still in cavity 50, it will get hit and pushed several times, thus reducing instances when hard plastic part 22 does not get completely ejected to a minimum.

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The machine controller 72 generates a data signal to an image processing system 70 that the ejector rods 56, 58 have been actuated.

Preferably, while mold 12 is opening, an image of the open mold half 16 is acquired by sensor device 330 via capture source 310 and
10 transmitted via spread-spectrum radio frequency, infrared signal communication platforms, or any other suitable wireless transmission system to analyzing means 340, preferably a host computer positioned at a physically remote location, wherein analyzing means 340 compares the image to an ideal image of mold half 16 as it should appear with
15 a properly formed plastic part 22 in cavity 50. If the image comparison shows that the mold cavity 50 is empty and that the hard plastic part 22 has been cleared from the mold half 16, the camera controller 70 sends a data signal to the machine controller 72 to actuate the ram 38 to close the mold 12 to start a new molding cycle.

20 On the other hand, if the image comparison shows that the hard plastic part 22 has not been dislodged from the cavity 50 or cleared from the mold half 16, the camera controller 70 sends a data signal to the machine controller 72 that the ram 38 is not allowed to close the mold 12, and a signal is generated via the machine controller 72

or the camera controller 70 to notify an operator to check the mold, clear any residual plastic or the hard plastic part 22 from the cavity 50 and mold 12, and then restart the plastic injection molding machine 10.

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In the preferred embodiment, sensor system 300 generally comprises image capture source 310, preferably near-IR sensor 310a and means for analyzing images 340 from the near-IR sensor 310a and for communicating the presence or absence of molded parts within mold halves 14 and 16 to machine controller 72. Analyzing means 340 is preferably a computer programmed for analyzing near-IR images to determine whether a part is present or absent in mold 12 and then communicates the results to part-forming machine controller 72. Given known parameters, one skilled in the art would be able to develop software for analyzing near IR images of mold 12. Analyzing means 340 is preferably integrated with machine controller 72; however, a separate controller/computer may be utilized that is that is communicationally linked with machine controller 72.

20 In the preferred embodiment of the present invention, as depicted in **FIG. 4**, sensing system 300 comprises image capture source 310, wireless image transfer system 320, sensor device 330 and analyzing means 340, wherein the analyzing means 340 is preferably a remotely positioned, wirelessly linked computer or microprocessor.

Image capture source 310 is positioned preferably within mold half 14, illustrated in **FIGS. 2-3**, facing toward the surface of mold half 16 such that the facing surfaces of mold half 16 and mold half 14 are positioned generally parallel to each other, wherein mold half 16 and mold half 14 separate along a relatively parallel direction of travel and wherein image capture source 310 is preferably in view of mold half 16 along the direction of travel and the parts formed by the machine 10 are preferably imageable by image capture source 310 during mold travel. The preferred positioning of capture source 310 enables image acquisition to begin as soon as sensor device 330 receives a wireless signal transmission from machine controller 72 that the mold is beginning to open, wherein preferably the first image is immediately acquired while mold 12 is opening, in lieu of waiting for a signal from machine controller 72 that mold 12 has completely opened. However, it should be noted that in alternate embodiments, such as is illustrated in **FIG. 5**, image capture source 310 may be positioned at various locations within the mold such that various parts or specific areas of parts may be imaged at any angle. It is also contemplated that any number of image capture sources 310 may be positioned at various positions within the mold to increase resolution and/or to improve the image analysis process.

By checking for a cleared mold half 16 with an empty cavity after every cycle or firing of the ejector system 18, rather than

after every several firings, it is expected that the ejector system 18 will rarely have to be actuated or fired more than once in a part molding cycle, thus saving both time and wear. In production lines where an injection molding machine 10 is automatically cycled to
5 continue producing plastic parts for weeks and months on end, the saved time can be significant and can allow each injection molding machine 10 to produce many additional parts in a year. For example, if all the hard plastic parts get ejected by the first ejector stroke in nine out of ten molding cycles, and if the hard plastic parts are
10 always ejected after five ejector strokes, then variable ejector cycling according to this invention could save at least thirty-six strokes when compared to ten fixed stroke cycles. Specifically, fifty strokes $(10 \text{ cycles} \times 5 \text{ strokes/cycle})$ minus fourteen strokes $(9 \text{ single strokes plus } 1 \times 5 \text{ strokes})$ equals thirty-six skipped ejector strokes.

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As one can see from the above description, the overall injection molding process is extremely time sensitive. Thus, incorporation of the present invention therewith improves on this time sensitive and critical process by preferably providing an integrated controller 100
20 that serves as both sensor controller 70 and machine controller 72. In the preferred embodiment, analyzing means 340 receives an electronic representation of the acquired image from sensor device 330, analyzes said image and wirelessly communicates the presence or absence of molded parts within mold 12 to part-forming machine

controller 72. Given known parameters, one skilled in the art would be able to develop software for analyzing the images of the mold 12.

Analyzing means 340 is preferably a physically remote host computer that is wirelessly and communicationally linked with part-forming machine controller 72. It is anticipated that analyzing means 340 could be a wireless, modular host computer system, wherein essentially unlimited portability would facilitate cooperative and shared utilization between a plurality of machine vision systems. It is also anticipated that analyzing means 340 could be integrated with, or a sub-component of, image capture device 310, wherein image capture device 310 could be an "intelligent" sensor with on-board image analysis capabilities and the ability to communicate analytical results to part-forming machine controller 72, wherein the functional process of the alternate "intelligent" sensor is diagrammatically illustrated in **FIG. 6**.

Although the preferred embodiment contemplates wireless components, integrated controller 100 can also be a personal computer having serial, parallel and or USB ports for connecting data inputs.

Known machine controller 72 programs are loaded into integrated controller 100. One or more sensory devices 20 are connected directly to one or more preexisting serial, parallel or USB ports of the integrated controller 100. It should also be noted that data cards specific for the respective sensor 20 and having a interface

port therein can be connected directly to the bus of the CPU of the computer to provide a connection means for the sensor 20. By programming integrated controller 100 or loading known software therein, integrated controller 100 can receive the input
5 signal(s)/data from sensory devices 20, analyze the data, provide an output signal to sensory devices 20 and communicate directly and contemporaneously with the preexisting machine controller 72 software. The above-described processes performed by the sensor controller 70 and the machine controller 72 can all now be performed
10 by the integrated controller 100. It should be noted that one skilled in the art with knowledge of the parameters and the desired result can program integrated controller 100 to analyze data and provide the appropriate signals to control part-forming machine 10.

15 Although the preferred embodiment of the present invention is described herein utilizing a near-infrared camera sensor 310a, any known sensory device such as, for exemplary purposes only, infrared sensors, ultrasonic sensors, or any other known sensing devices may be utilized.

20 The preferred wireless image functional process of the present invention is diagrammatically represented in **FIG. 1**. Image capture source 310 preferably enables capture of light waves and/or radiation, preferably at near-infrared wavelengths. It is

contemplated that image capture source 310 could be a digital camera, video camera, image scanner or any other suitable type of data collection terminal and/or optical imager. The image captured thereby is preferably allowed to travel wirelessly to sensor device 5 330 via wireless image transfer system 320. Wireless image transfer system 320 preferably incorporates appropriate wireless transmission capabilities, such as, for exemplary purposes only, spread-spectrum radio frequency or infrared signal communication platforms, wherein image capture source 310 preferably generates computer readable image 10 data of the optically imaged visual representation and wherein such creation of the electronic image facilitates digitization and transmission thereof for reading and/or analysis at a remote location. The image may be in any suitable format such as, for exemplary purposes only, mega pixel format, video graphic array 15 (VGA), common intermediate format (CIF), quarter common intermediate format (QCIF), or any other format suitable for such an image capture and transmission application.

Wireless image transfer system 320 allows the image of mold half 20 16 and/or part 22 to be viewed remotely by sensor device 330, thus preventing the sensor device from being exposed to the high temperatures of mold 12. Preferably, as more fully described above, sensor device 330 is positioned within mold half 16, however, in alternate embodiments, sensor device 330 may be positioned remotely

to the mold half 14, may be positioned external to mold half 14, or within one of mold halves 14, 16 at a lower temperature point from the part-forming area such that the sensor device 330 is not damaged by the high temperatures. It is also contemplated that the sensor device 330 may be thermally insulated and/or have various known heat removal systems to protect sensor device 330 and to facilitate the preferred positioning within the mold.

Image capture source 310 is preferably a near-infrared camera 310a. However, in alternate embodiments, image capture device 310 may be a complementary metal-oxide semiconductor (CMOS) image sensor, thereby enabling sensor device 330 to randomly access specific pixels on the sensor array, or any other imaging device such as, for exemplary purposes only, a charge coupled device (CCD) array, electronic camera, an infrared camera or infrared heat sensor. Additionally, image capture source 310 could be a coherent fiber optic bundle, wherein light waves and/or radiation could be captured thereby and allowed to travel therethrough to sensor device 330 via linking member 320. Linking member 320 could also be coherent fiber optic bundles. The coherent fiber optic bundles allow the image of the mold half 16 and/or part 22 to be viewed remotely by sensor device 330, thus preventing the sensor device from being exposed to the high temperatures of the mold.

It is preferred that machine controller 72 is wirelessly enabled for the transmission/reception of input/output data. Like the image data, the I/O data may be communicated via any type of wireless transmission, such as, for exemplary purposes only, spread-spectrum radio frequency or infrared signal communication platforms.

It is also anticipated that, in order to accommodate individual application preferences, the present invention could be utilized with only image data transfer occurring via a wireless format, or, alternatively, with only I/O data transfer occurring via a wireless format, wherein the other data component could incorporate a traditional hard-wire transfer system.

Preferably, the sensor or camera of sensor device 330 is held at a minimized and/or relatively parallel angle with the target, wherein the view area for each pixel is generally free from distortion, thereby resulting in an image having higher resolution. As a result, more accurate analysis can be made with images having better resolution. Also preferably, the sensor or camera of sensor device 330 receives commands and transmits image data via a wireless communication link. As previously discussed and as shown in **FIG. 7**, the prior-art method of placing the vision system on top of the mold results in a skewed view as the angle of the target increases relative to the camera. Consequently, a larger view area for each pixel 400 results thereby decreasing the resolution of the image. In

the present invention, however, as shown in **FIG. 8**, the sensor or camera is held at a relatively parallel angle with the target, and as such, the view area for each pixel is smaller and more consistent thereby resulting in an image having higher resolution. As a result, more accurate analysis can be made with images having better resolution.

In the preferred embodiment, sensor device 330 has an illumination source that can directly illuminate part 22 and/or mold 12 at a substantially parallel angle thereto. As a result, better lighting of the target area is possible thus increasing the clarity and accuracy of the acquired image.

It should be noted that although the above sensory inspection system and method is described in combination for use with a skip-eject system, it may be utilized with any part-forming machine or any other type of automated or semi-automated production, inspection and/or assembly system wherein machine sensory inspection analysis may be incorporated. It should also be noted that any number of sensor devices 330 and/or capture sources 310 may be utilized, wherein more than one sensor device 330 and/or capture source 310 may transmit image data via wireless transmission to remote host computer for subsequent analysis.

It should also be noted that an infrared (IR) emitting source, known within the art, may be utilized, wherein the source emits IR or near IR frequencies to assist in imaging the mold/part. An IR filter may also be utilized, wherein non-IR frequencies are blocked from entering the IR sensors, thus allowing IR frequencies to pass.

It should be further noted that wireless image transfer system 320 could also include a buffer, wherein the buffer could be integrated on a single chip to temporarily store image data for subsequent and/or generally contemporaneous transmission.

It should also be noted that while it is preferred that the combination of wireless system components is maximized, that is, that the sensory devices, the controller of the sensory devices, the host computer(s) components, and available modular components of an automated or semi-automated system are capable of sending and receiving wireless transmissions, any combination thereof could be utilized, wherein one or more components could be wireless and another component or components could be wired.

It should also be noted that while it is preferred that both a wireless image data acquisition and transfer system and a wireless input/output data transmission and control system are utilized to maximize the efficiency, modularity, and overall benefits of the

present invention, either wireless component could be utilized individually, wherein the other component could be traditionally hard-wired.

5 It should further be noted that, in an alternate embodiment, image capture device 310 could have built-in analysis capabilities, wherein image analysis could be self-conducted and communicated to the machine controller thereby, and wherein one skilled in the art could provide software to direct machine performance in response to
10 communications from a plurality of such intelligent sensors in machine systems utilizing multiple imaging devices or cameras.

 Having thus described exemplary embodiments of the present invention, it should be noted by those skilled in the art that the
15 within disclosures are exemplary only, and that various other alternatives, adaptations, and modifications may be made within the scope of the present invention. Accordingly, the present invention is not limited to the specific embodiments illustrated herein, but is limited only by the following claims.